A Performance Study of the ATN COTP Over the VDL Mode 3 Subnetwork

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Background and Purpose

- MITRE's Center for Advanced Aviation System Development (CAASD) has been supporting the Federal Aviation Administration (FAA) in the development of Very High Frequency (VHF) Digital Mode 3 air/ground subnetwork
- Previously presented modeling and simulation results of VDL Mode 3 subnetwork in the Aeronautical Telecommunication Network (ATN) environment
- Present modeling and simulation results on the effect of changing various ISO 8073 Connection-Oriented Transport Protocol (COTP) Class 4 parameter values

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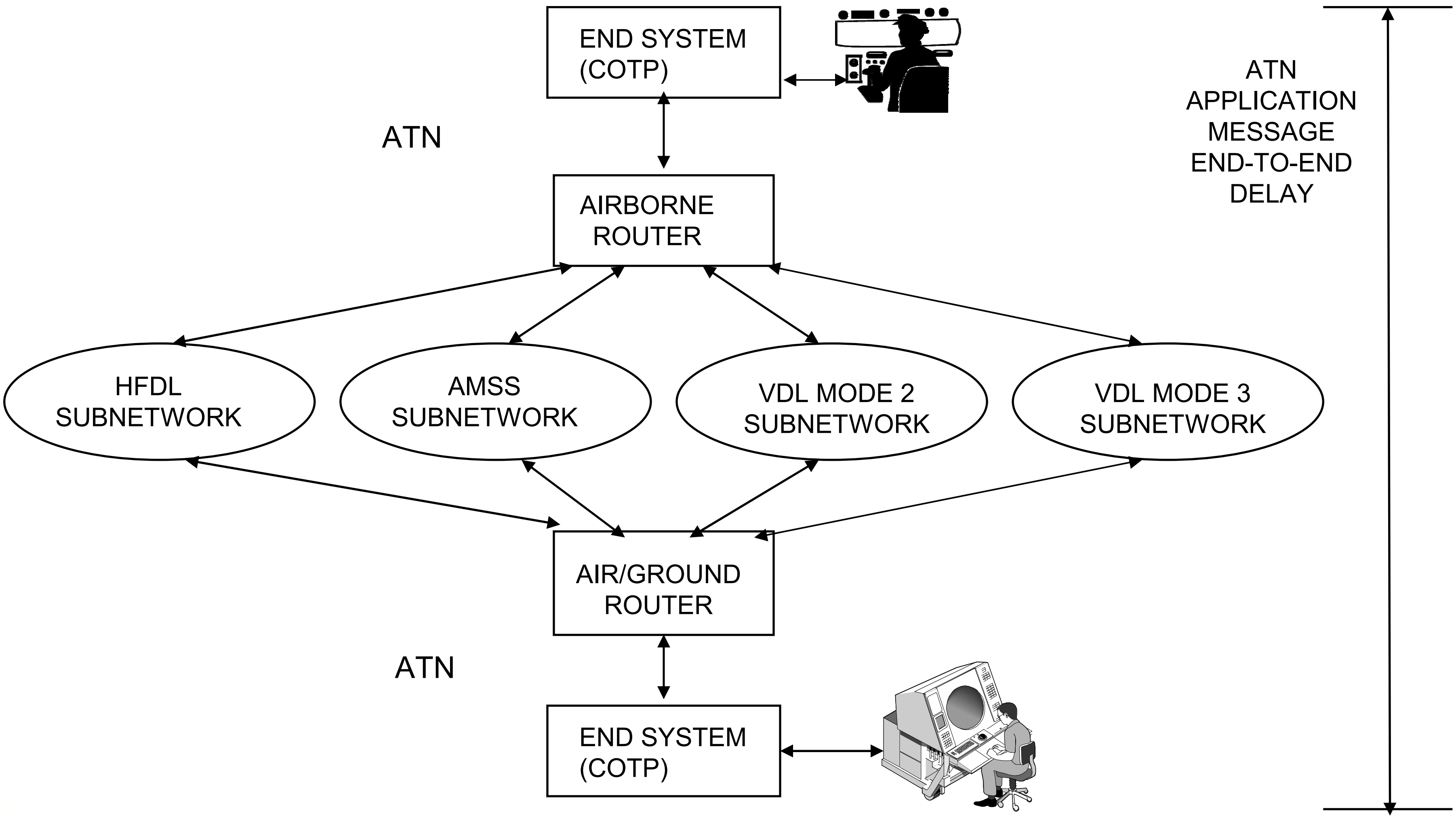
ATN



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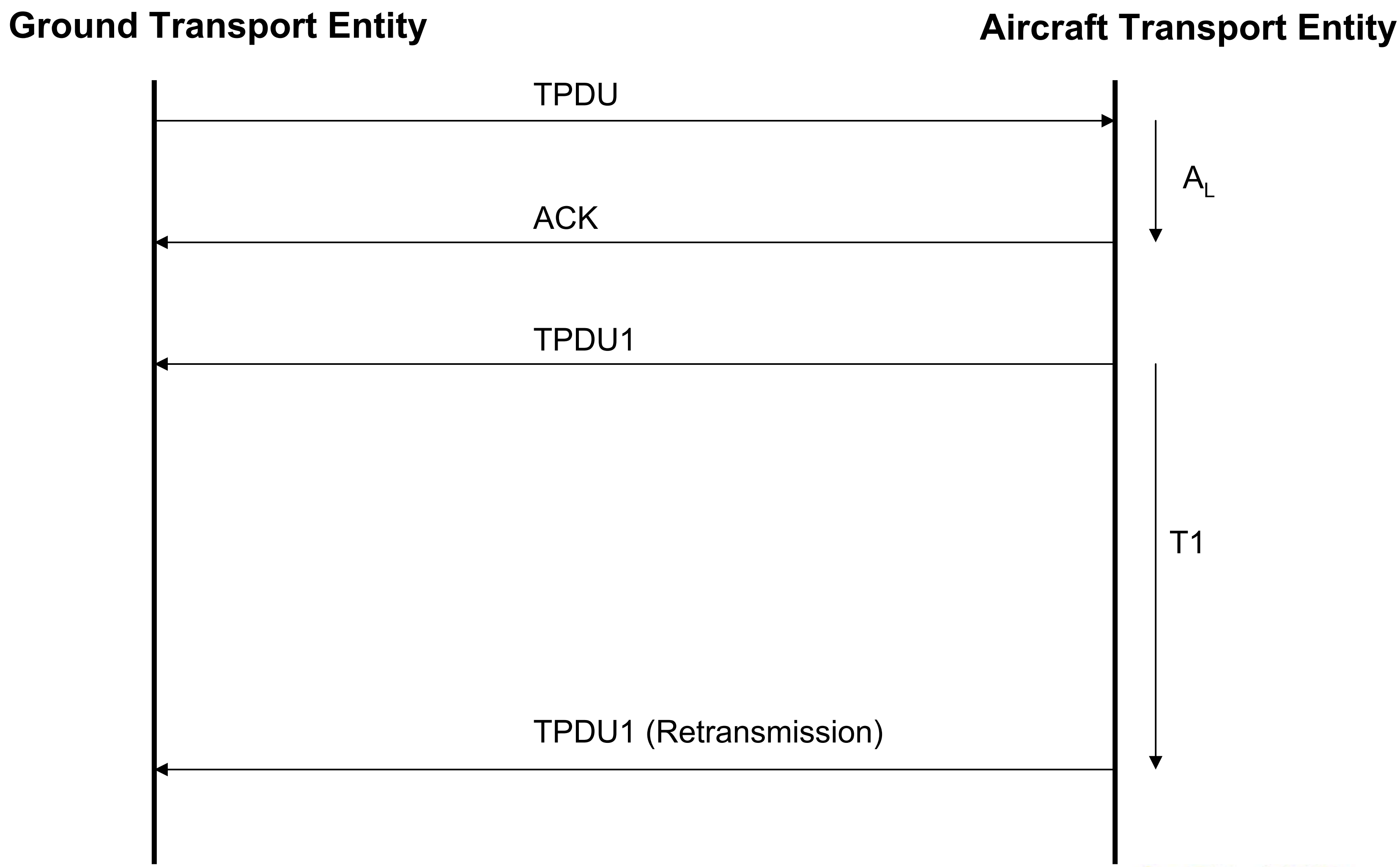
COTP

- ATN uses COTP Class 4 to provide a reliable data transport service between End Systems (ESs)
- Studied the effect of varying the values of the following 2 COTP parameters:
  - A_L (Local Acknowledgement Time)
    - The maximum time which can elapse between the receipt of a Transport Protocol Data Unit (TPDU) and the transmission of the corresponding acknowledgement (ACK)
    - 20 seconds in ICAO Doc 9705 (ATN Standards and Recommended Practices) first and second editions
    - 1 second in ICAO Doc 9705 third edition
  - T1 (Local Retransmission Time)
    - The maximum time the local transport entity will wait for an acknowledgement before retransmitting a TPDU

COTP A_L and T1 Parameters



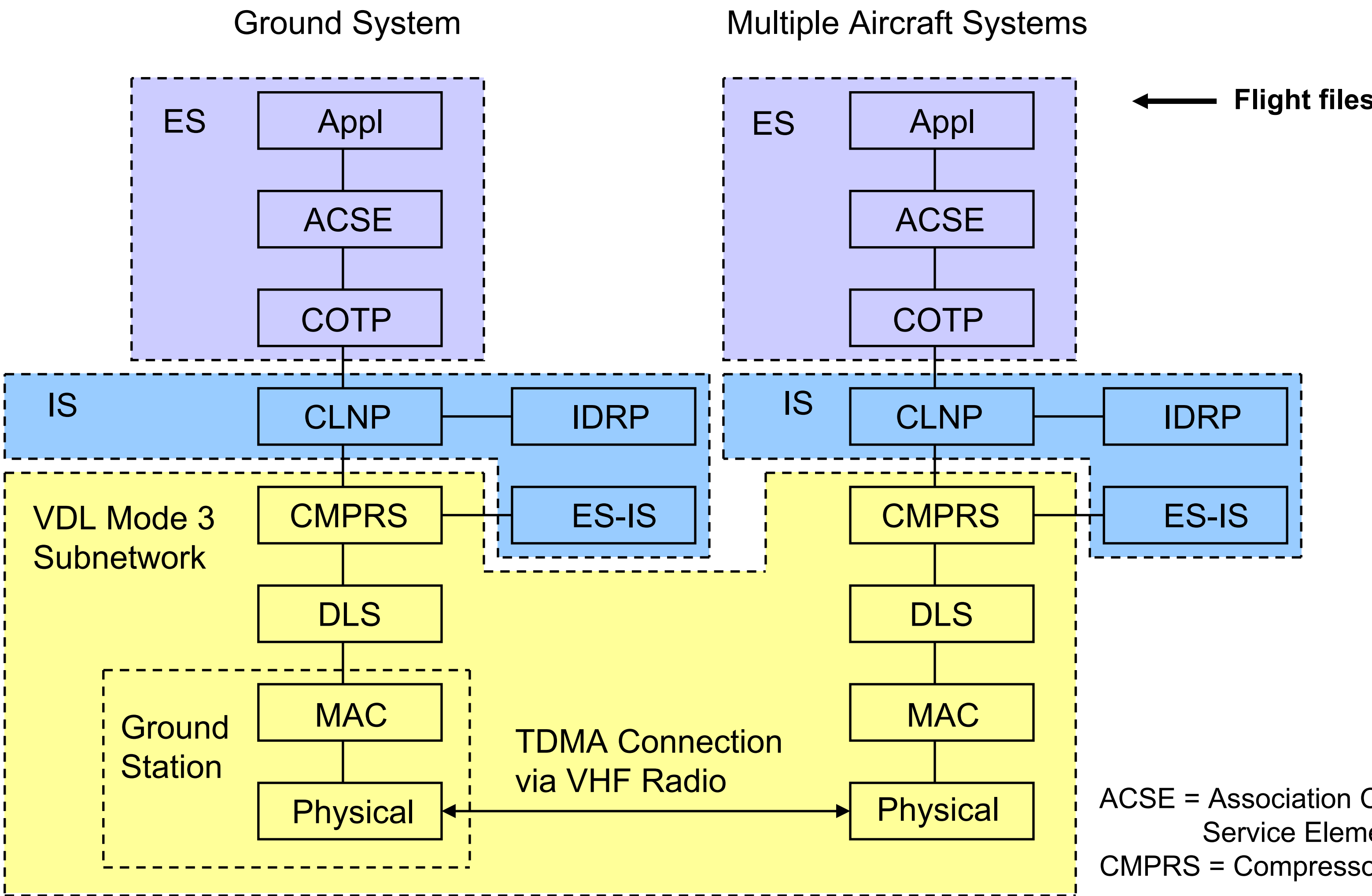
T1 Values

- In ISO 8073 and first and second editions of ICAO Doc 9705, T1 is defined by: $T1 = E_{LR} + E_{RL} + A_R + x$
  - E_{LR} is the expected maximum transit delay local-to-remote (100 seconds)
  - E_{RL} is the expected maximum transit delay remote-to-local (100 seconds)
  - A_R is the remote acknowledgement time (1 or 20 seconds)
  - x is the local processing time for a TPDU (1 second)
- In the third edition of ICAO Doc 9705, a Dynamic Local Retransmission Time Adaptation (DLRTA) algorithm is defined. Based on Jacobson's algorithm. It dynamically estimates the Round-Trip Time (RTT) between the transmission of a TPDU and its acknowledgement

Methodology

- Created integrated VDL Mode 3 2 Voice 2 Data (2V2D)/ATN models with 18, 26, 34, and 44 aircraft using OPNET Modeler by OPNET Technologies, Inc.
- Performed simulations using the terminal domain application message traffic model with different amount of traffic per aircraft
- Collected the following performance data:
  - High-priority 95th percentile downlink delays
  - Downlink throughputs at the VDL Mode 3 Media Access Control (MAC) and ATN application layers
- Collected the total number of TPDU retransmissions and maximum number of transmissions (N)

An Integrated VDL Mode 3/ATN Model



ACSE = Association Control Service Element
CMPRS = Compressor

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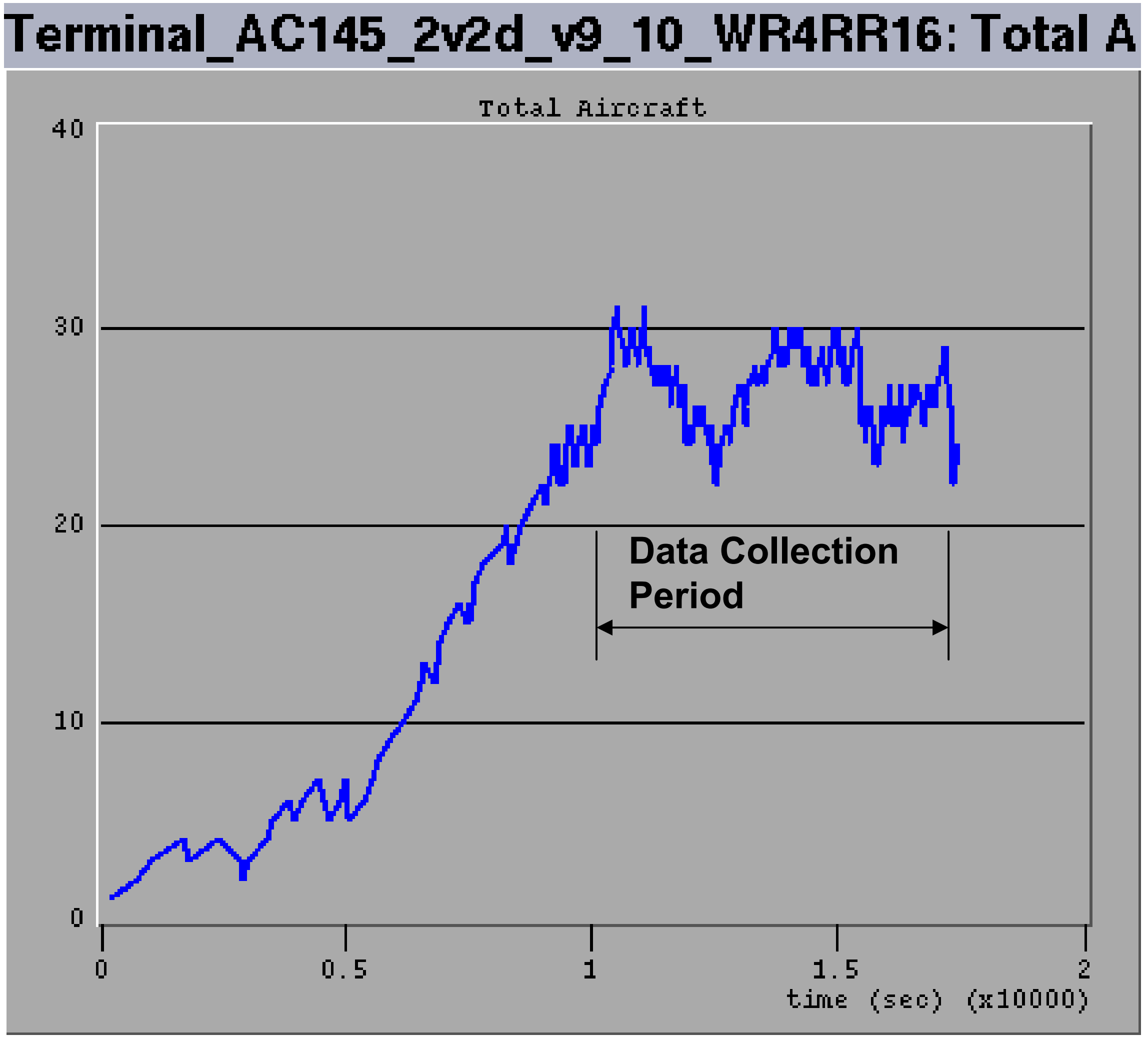
Number of Aircraft During Simulation for the 26 Aircraft Model



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Terminal Domain Application Message Model

Application Message Distribution	Priority (Note 7)	Uplink (From Ground Station)		Downlink (From Aircraft)	
		Average message rate	Average size in bits	Average message rate	Average size in bits
Exponential inter-arrival with Poisson message size (Point-to-point)	High	0.017	137	0.024	110
	Medium	0.0017	198	0.0008	100
	Low	0.001	2400	0.002	2400
Constant (Notes 4 & 5) (Broadcast)	Low	0.017	3325	0.0033	1760

Notes:
1. Rates are in number of messages per second per aircraft
2. Each message is acknowledged at the Data Link Sublayer except broadcast
3. Ack of uplink message uses downlink M Subchannels; ack of downlink message required 4 octets conveyed in the V/D (data) subchannels
4. Uplink broadcast messages are represented by constant uplink messages
5. Periodic fixed size downlink meteorological observations
6. All traffic collectively represents a Load Factor of 1
7. Each priority has its own COTP connection except for broadcast messages

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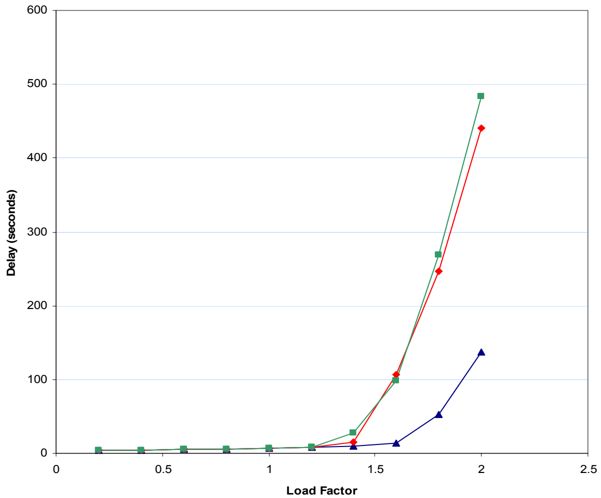
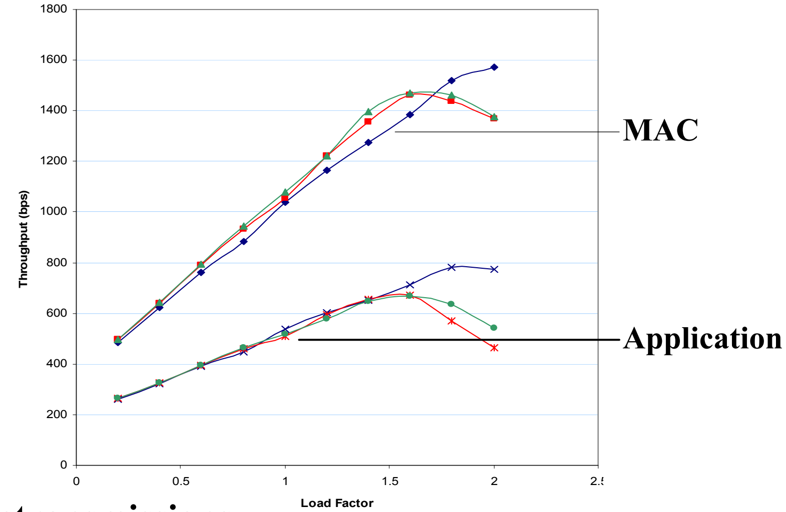
34 AC High-Priority Downlink Message 95th Percentile Delay, MAC and Application Layers DL Throughput, and Total Number of Retransmissions

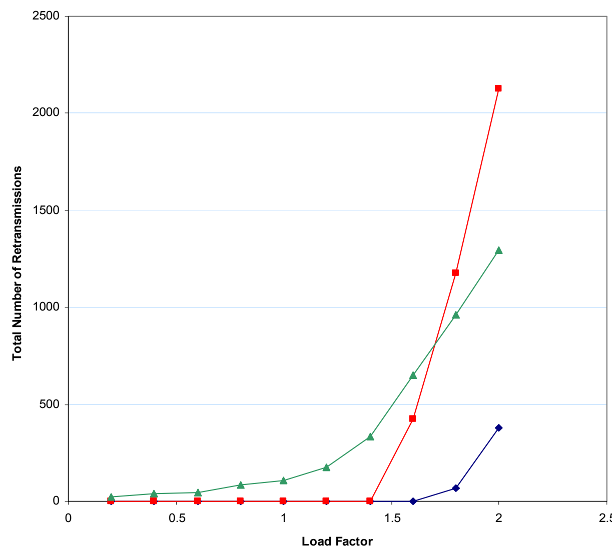
Downlink Message Delay



Downlink Throughput



Total Number of Retransmissions



A_L = 20 sec, T1 = 221 sec

A_L = 1 sec, T1 = 202 sec

A_L = 1 sec, T1 = DLRTA

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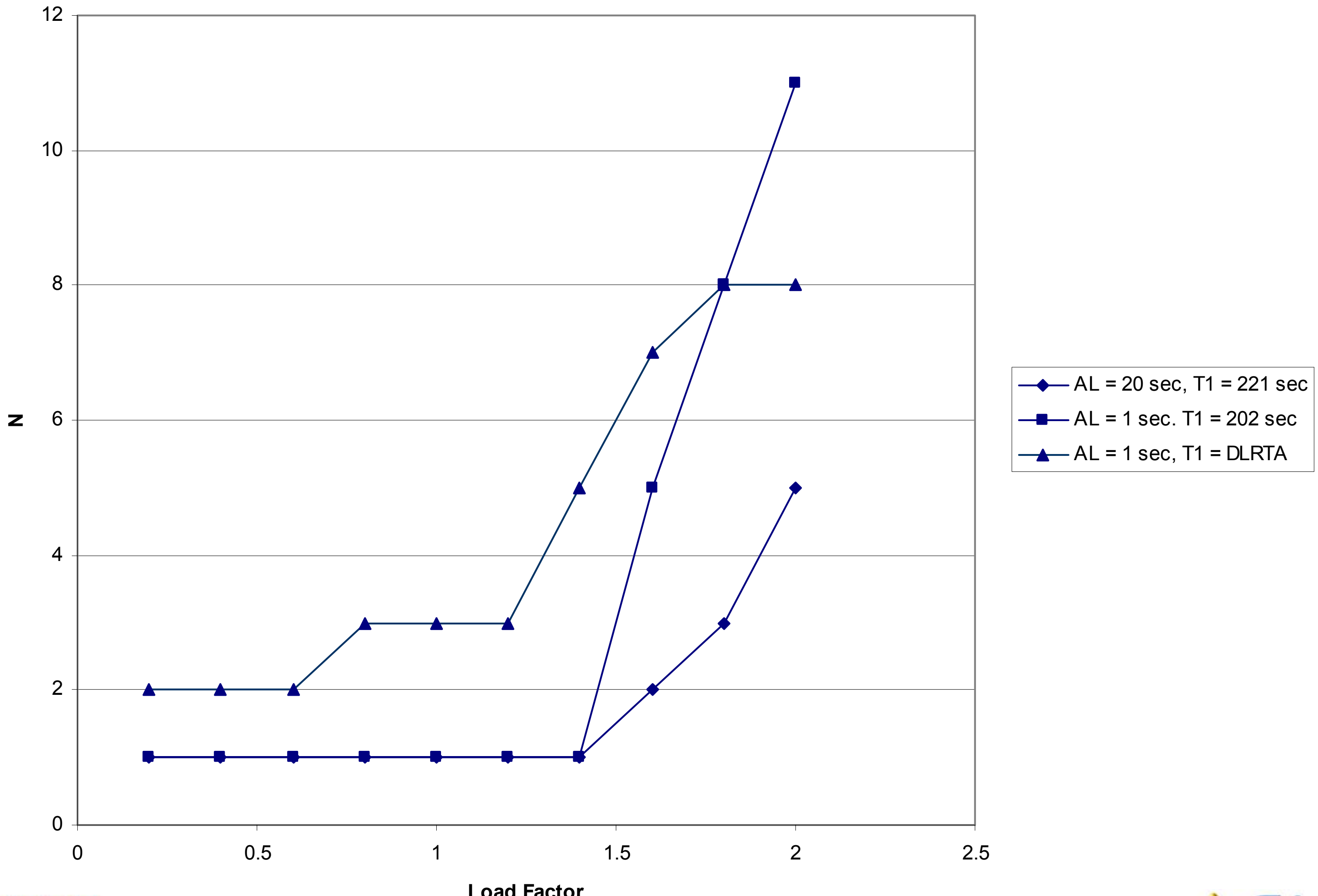
34 AC Maximum Number of Transmissions (N)



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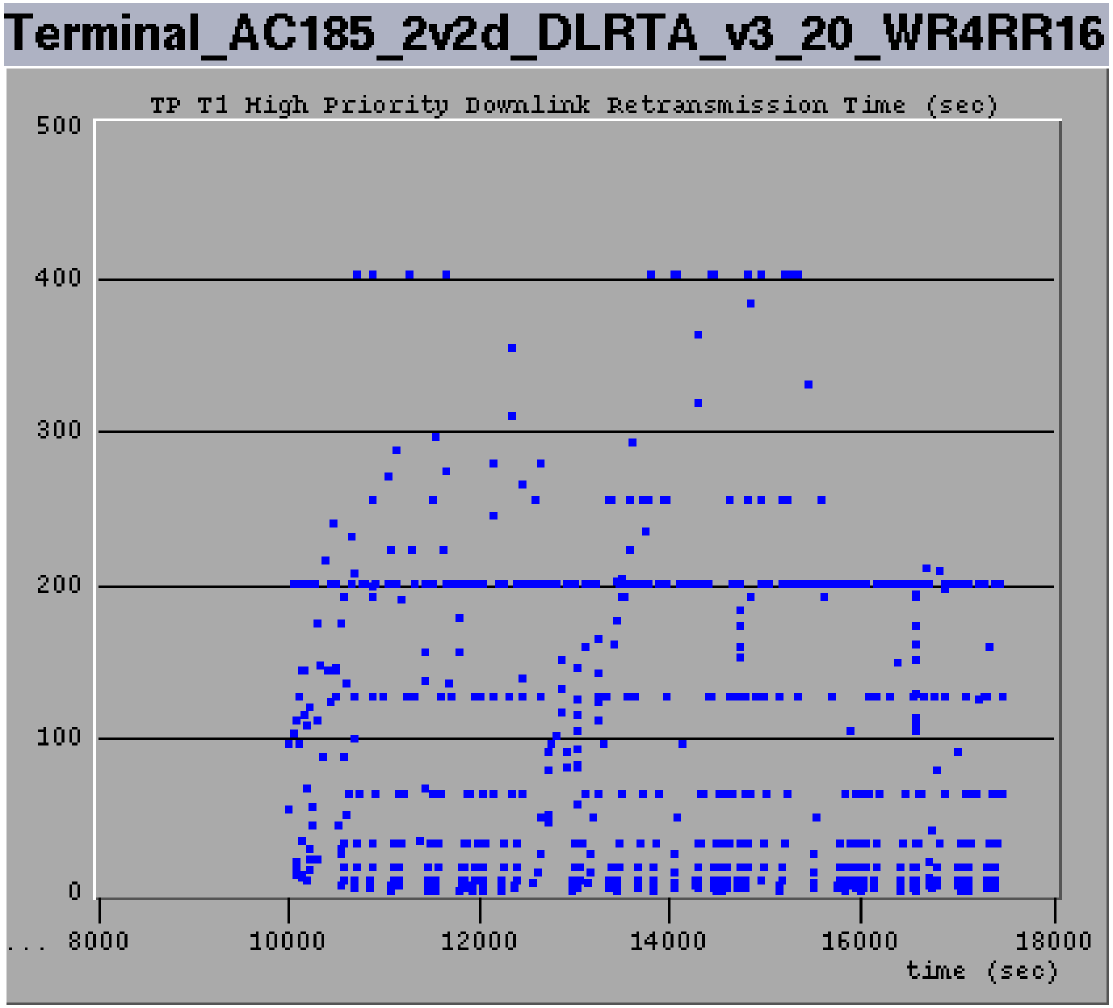
34 AC T1 Values Using DLRTA Algorithm (2 LF)



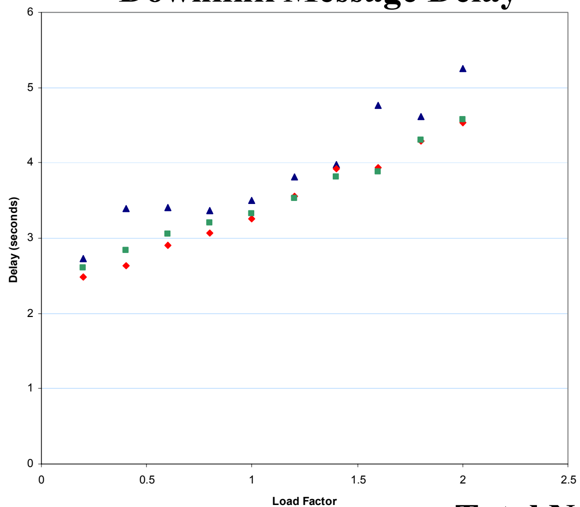
Summary and Observations

- Presented modeling and simulation results on the effect of changing various COTP Class 4 parameter values
- There does not appear to be much performance difference between different values of A_L and T1 at low LFs (and low number of aircraft)
- There does not appear to be any significant performance improvement using DLRTA algorithm for T1
- A_L = 20 sec and T1 = 221 sec appear to perform better at higher LFs (and larger number of aircraft) compared with the other A_L and T1 values

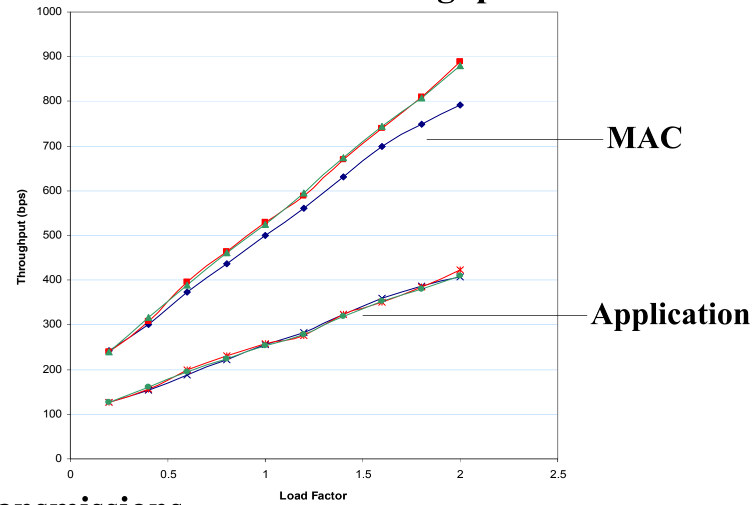
Backup Slides

18 AC High-Priority Downlink Message 95th Percentile Delay, MAC and Application Layers DL Throughput, and Total Number of Retransmissions

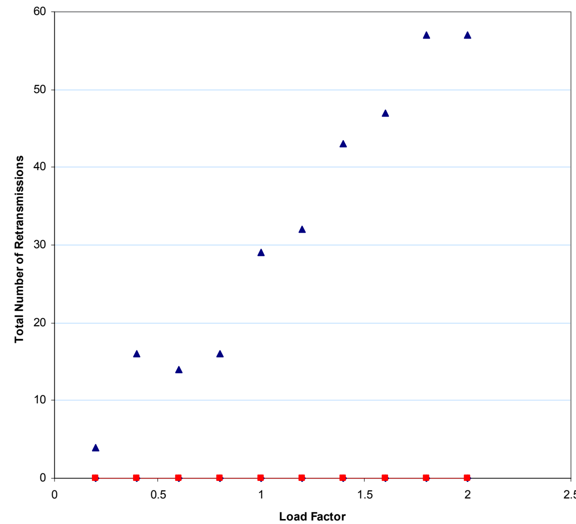
Downlink Message Delay



Downlink Throughput



Total Number of Retransmissions



A_L = 20 sec, T1 = 221 sec

A_L = 1 sec, T1 = 202 sec

A_L = 1 sec, T1 = DLRTA

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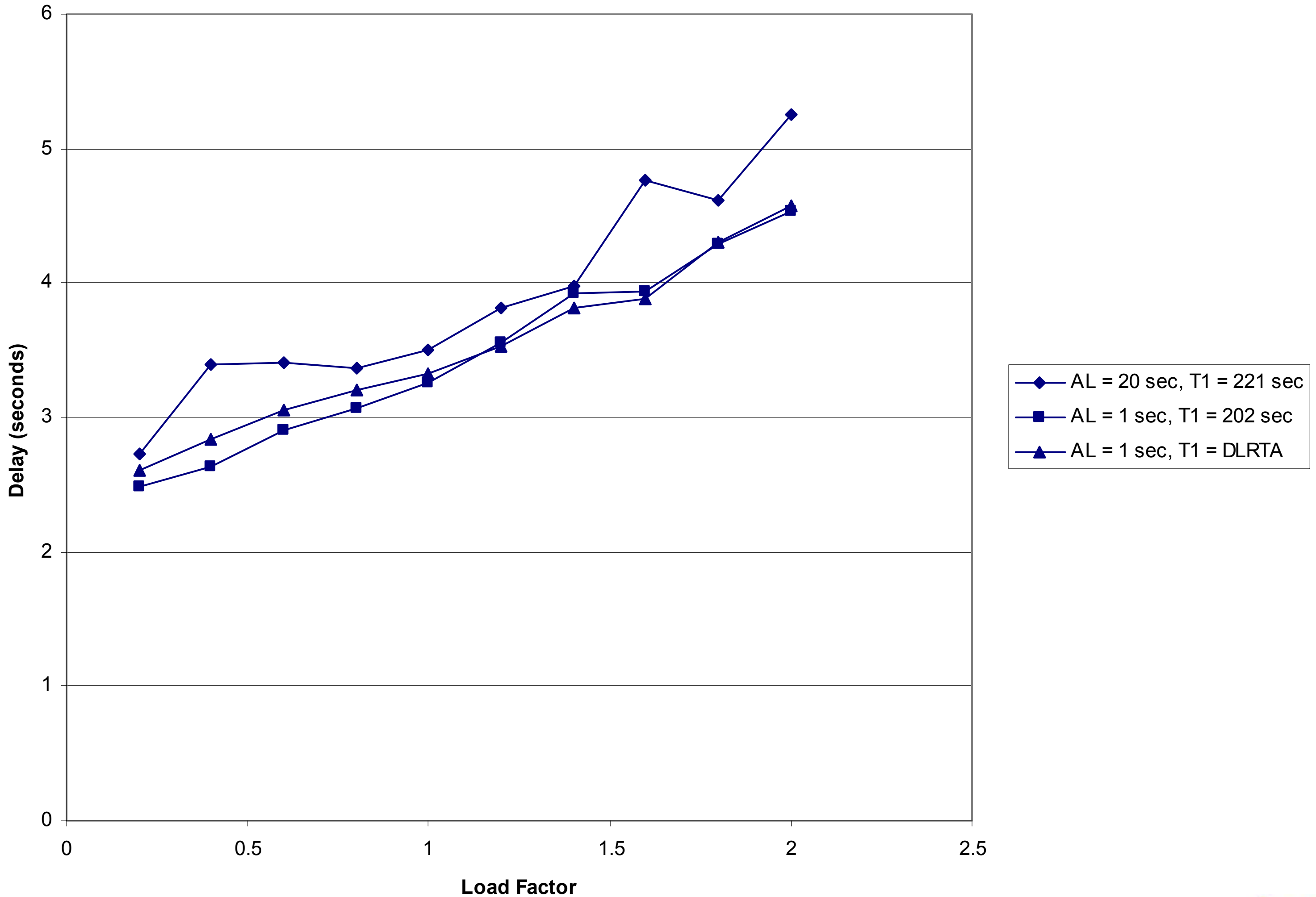
Pros and Cons of Longer A_L Values

Pros	Cons
May allow the acknowledgement of more than one received TPDUs with the same ACK	Lengthens the round-trip time that can be observed by the remote transport entity and the time of detection of PDU loss
May provide the opportunity to concatenate an ACK PDU with a data (DT) PDU	Fewer ACKs may cause needless retransmission timeouts in lossy environments
	May cause congestion on the network
	May affect the speed of transmission window adjustment
	May reduce the system efficiency and throughput

VDL Mode 3 MAC Parameters

- RE (Net Entry Request Randomizer) 16
- WE (Net Entry Retransmission Delay) 4
- RR (Reservation Request Randomizer) 16
- WR (Reservation Request Retransmission Delay) 4
- NM1 (Maximum Retry) 20

18 AC High-Priority Downlink Message 95th Percentile Delays



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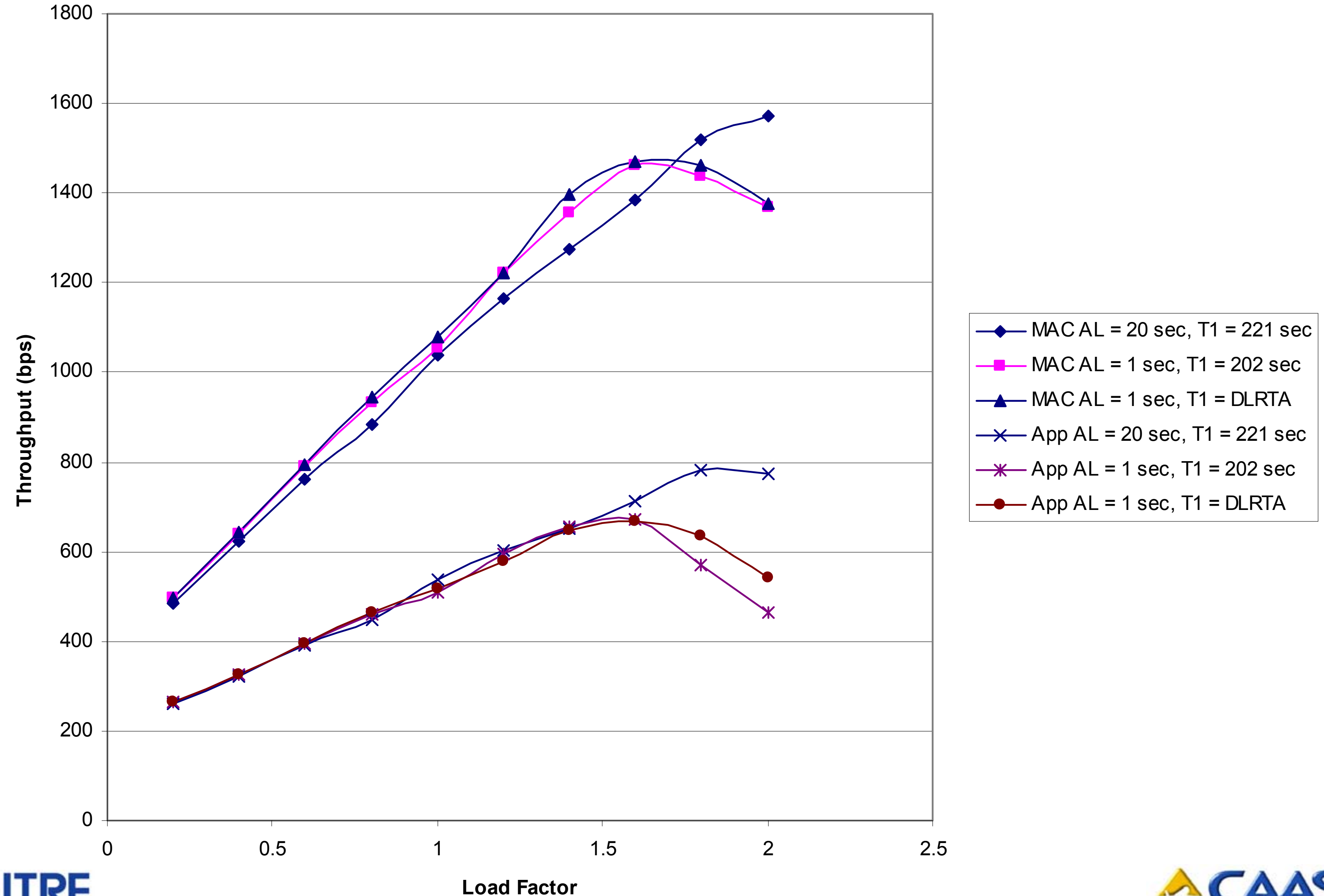
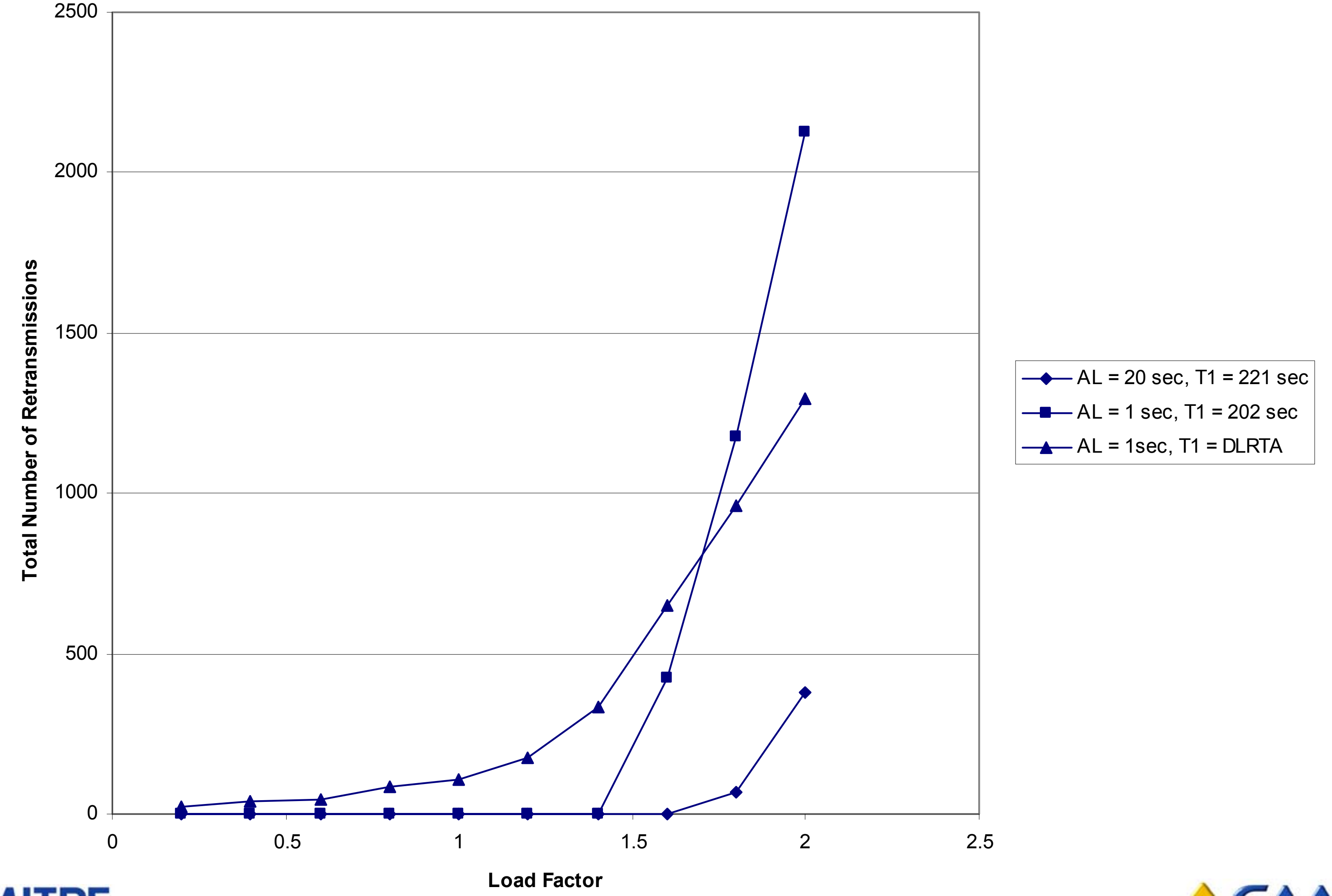
34 AC MAC and Application Layers Downlink Throughputs



34 AC Total Number of Retransmissions



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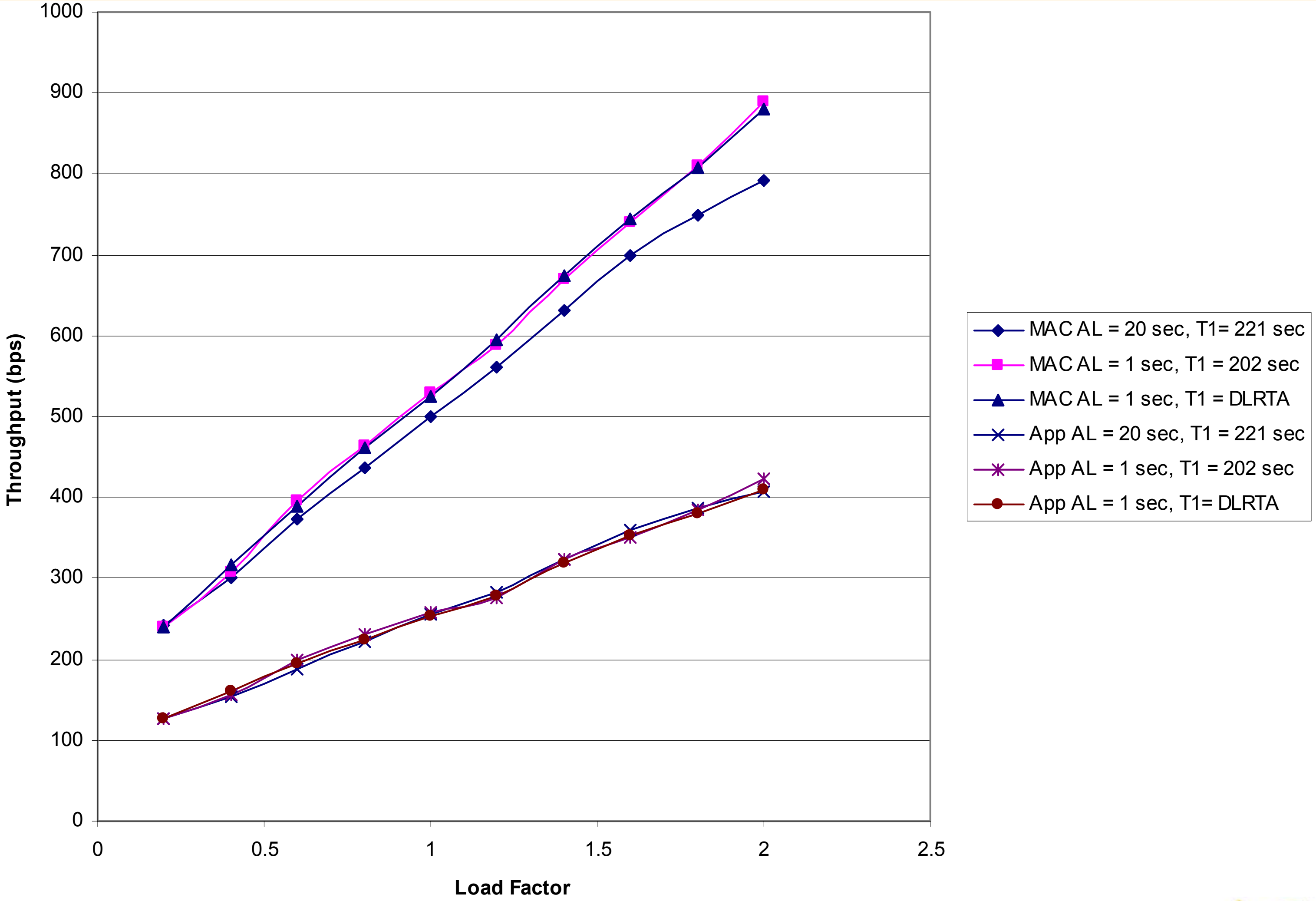

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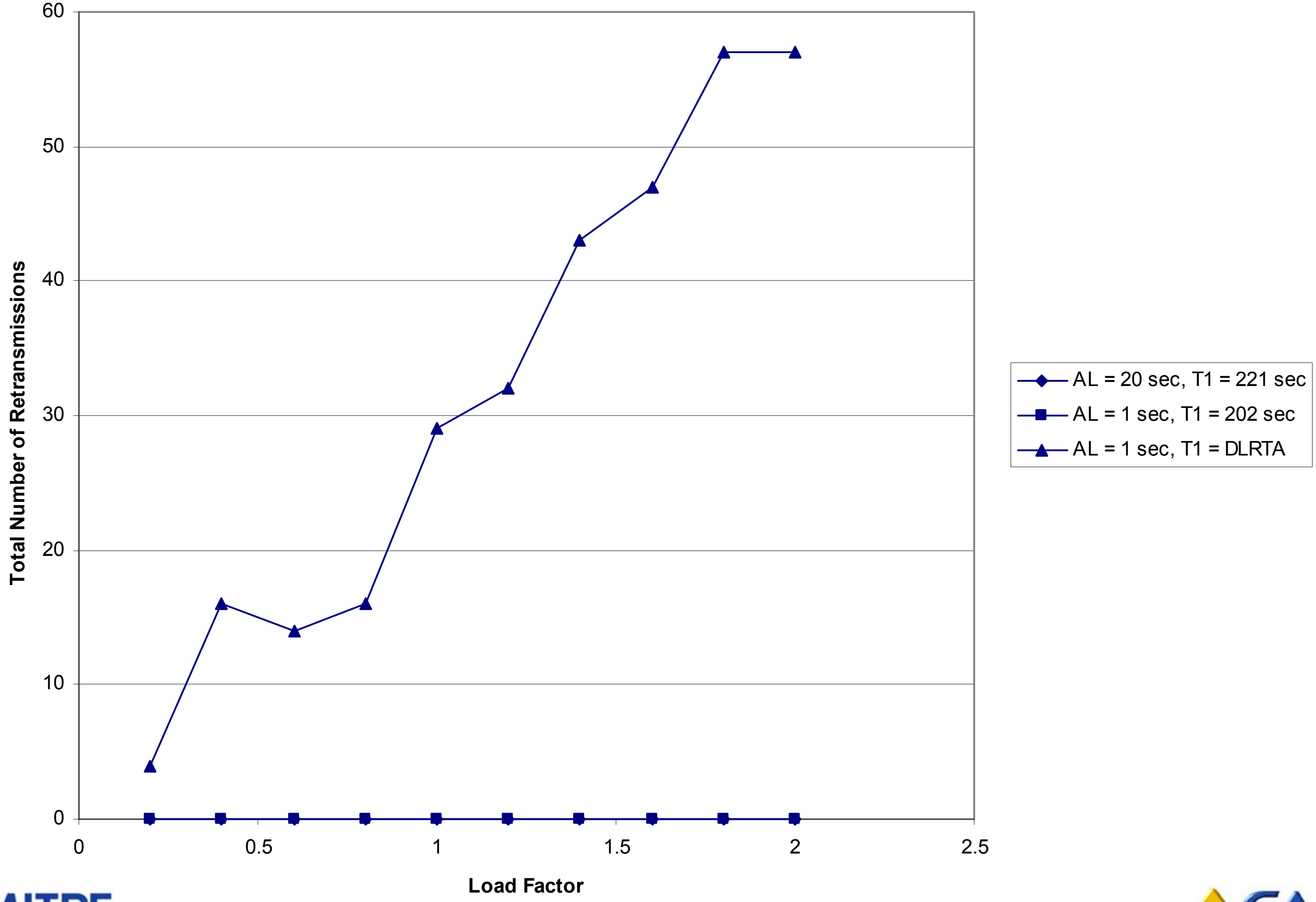

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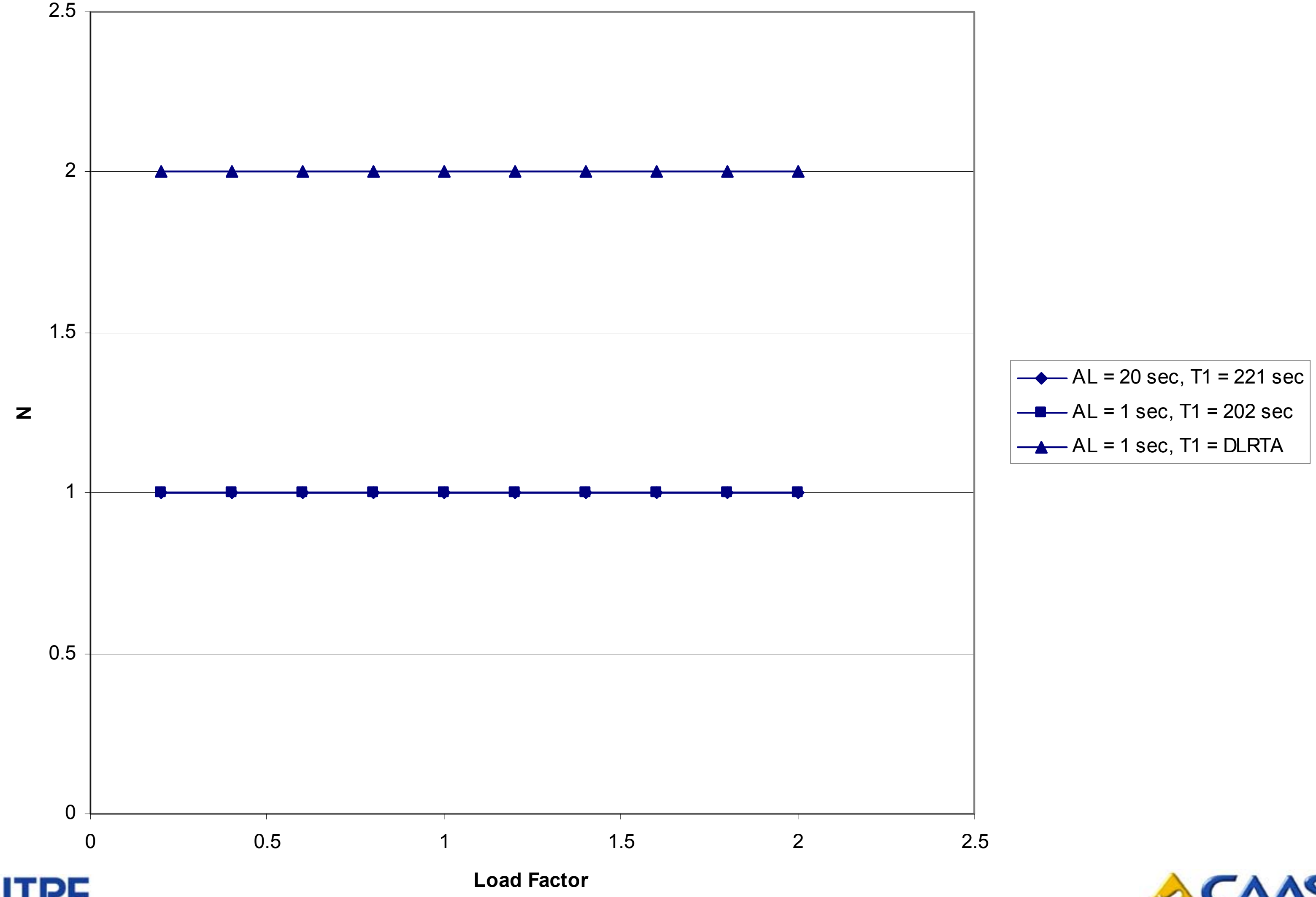
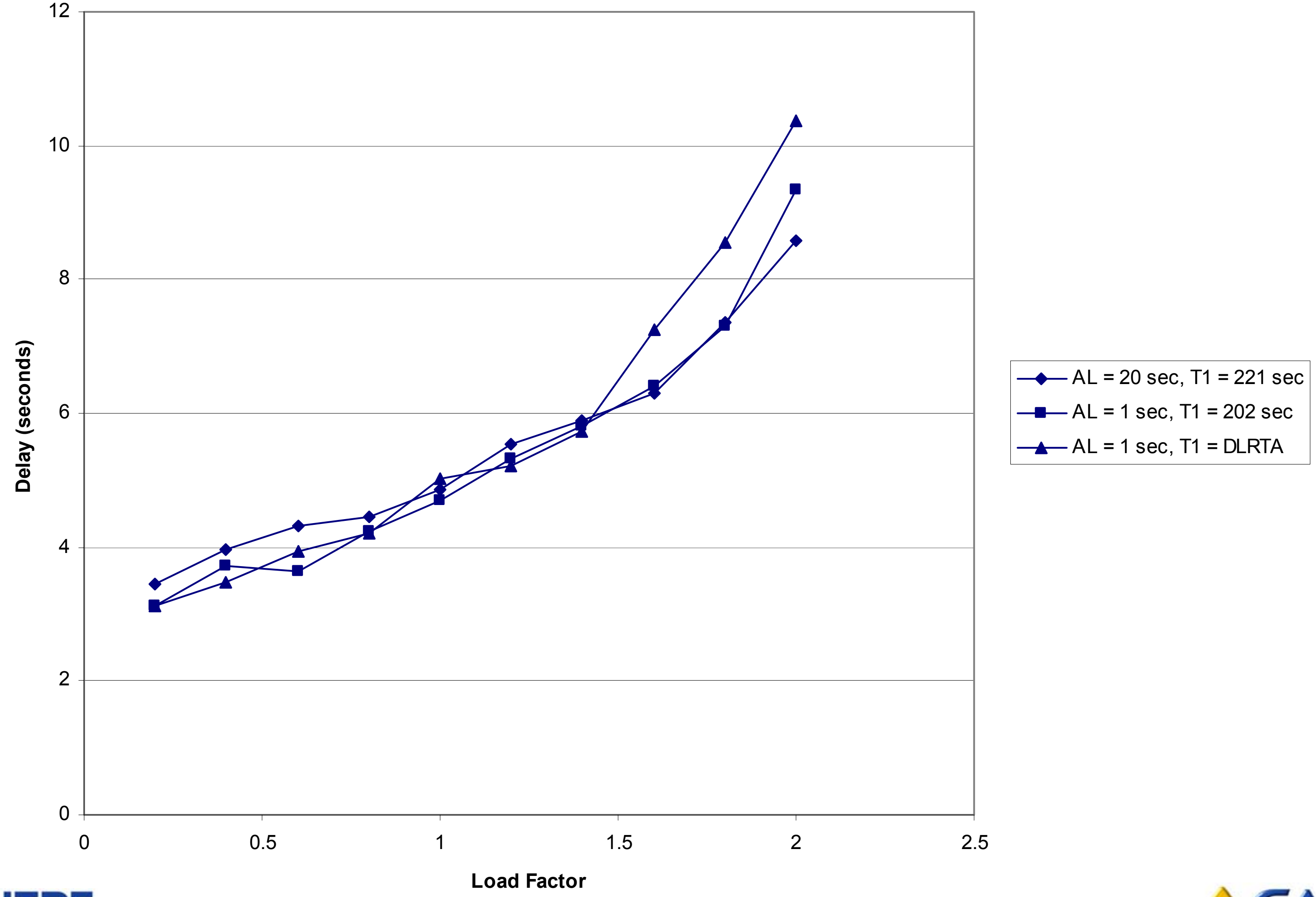
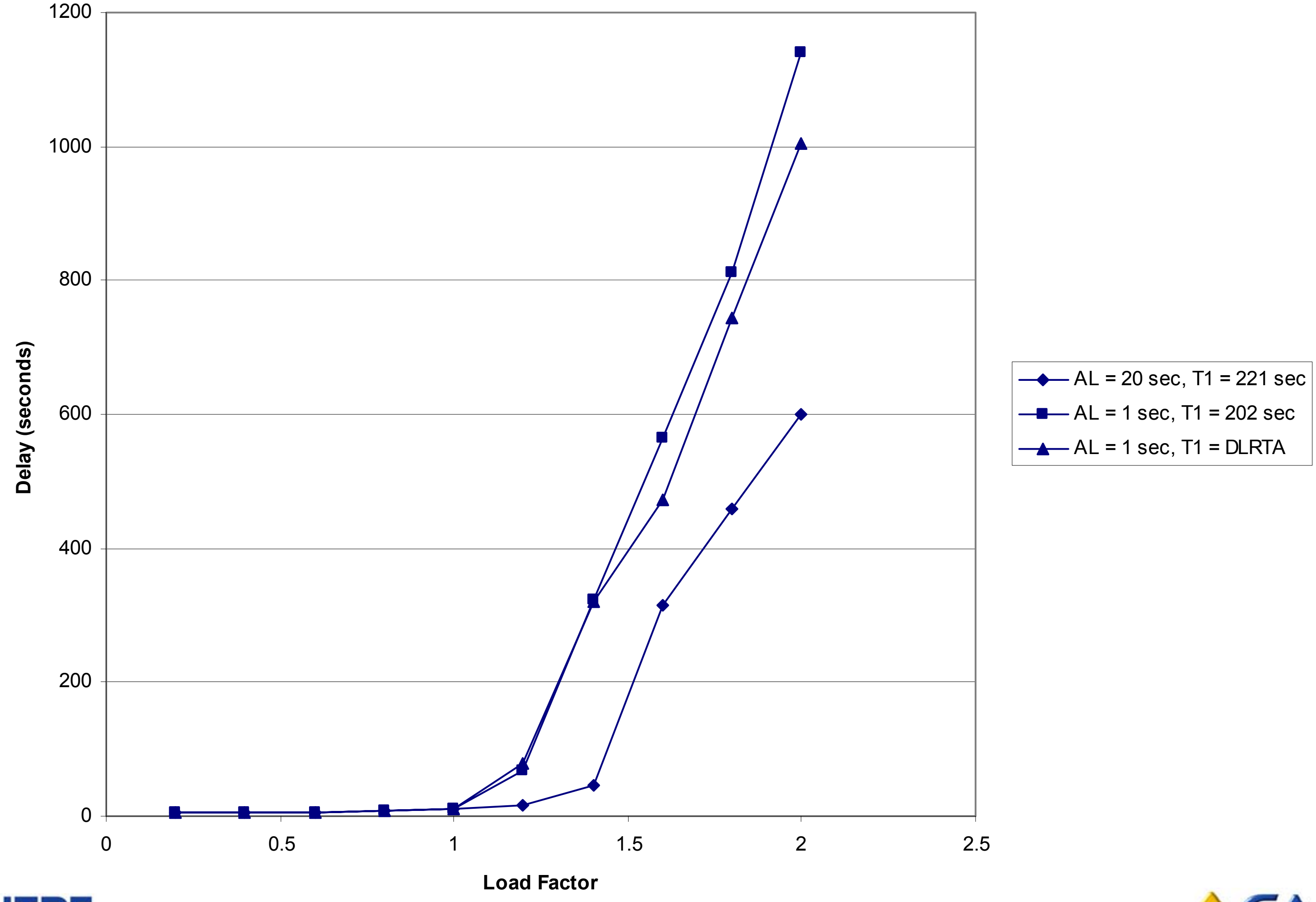
18 AC Maximum Number of Transmissions (N)



26 AC High-Priority Downlink Message 95th Percentile Delays



44 AC High-Priority Downlink Message 95th Percentile Delays



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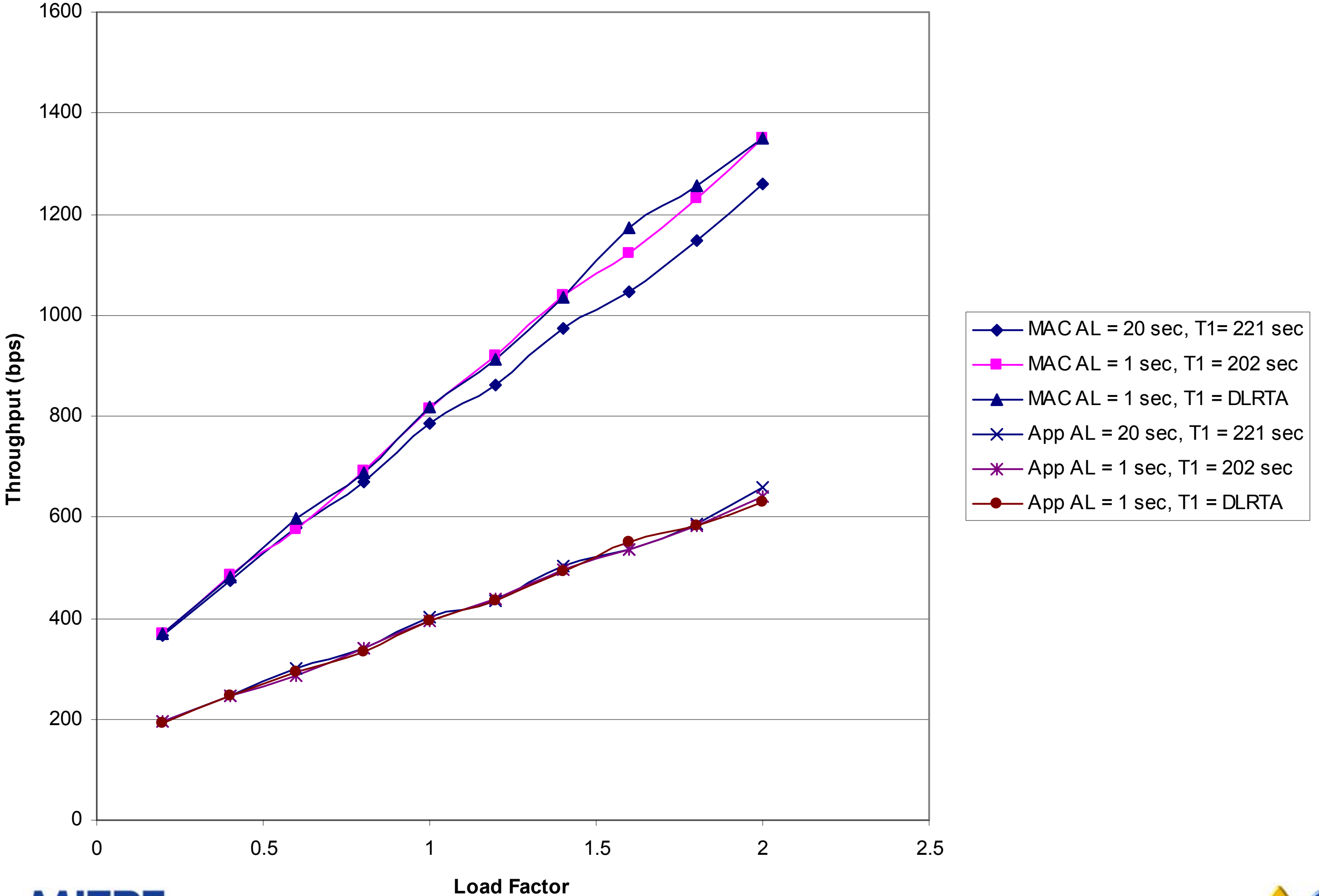
26 AC MAC and Application Layers Downlink Throughputs



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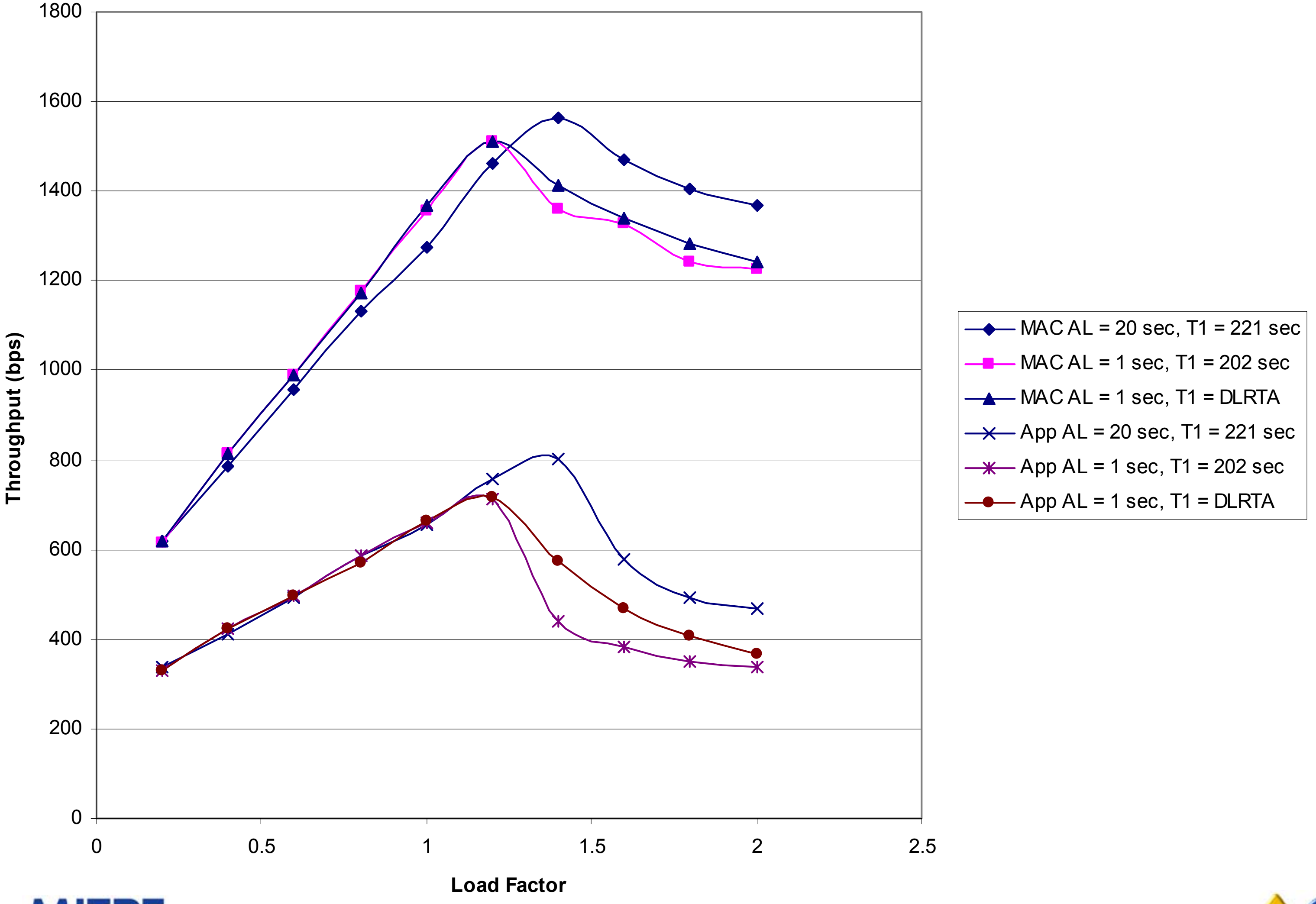
44 AC MAC and Application Layers Downlink Throughputs



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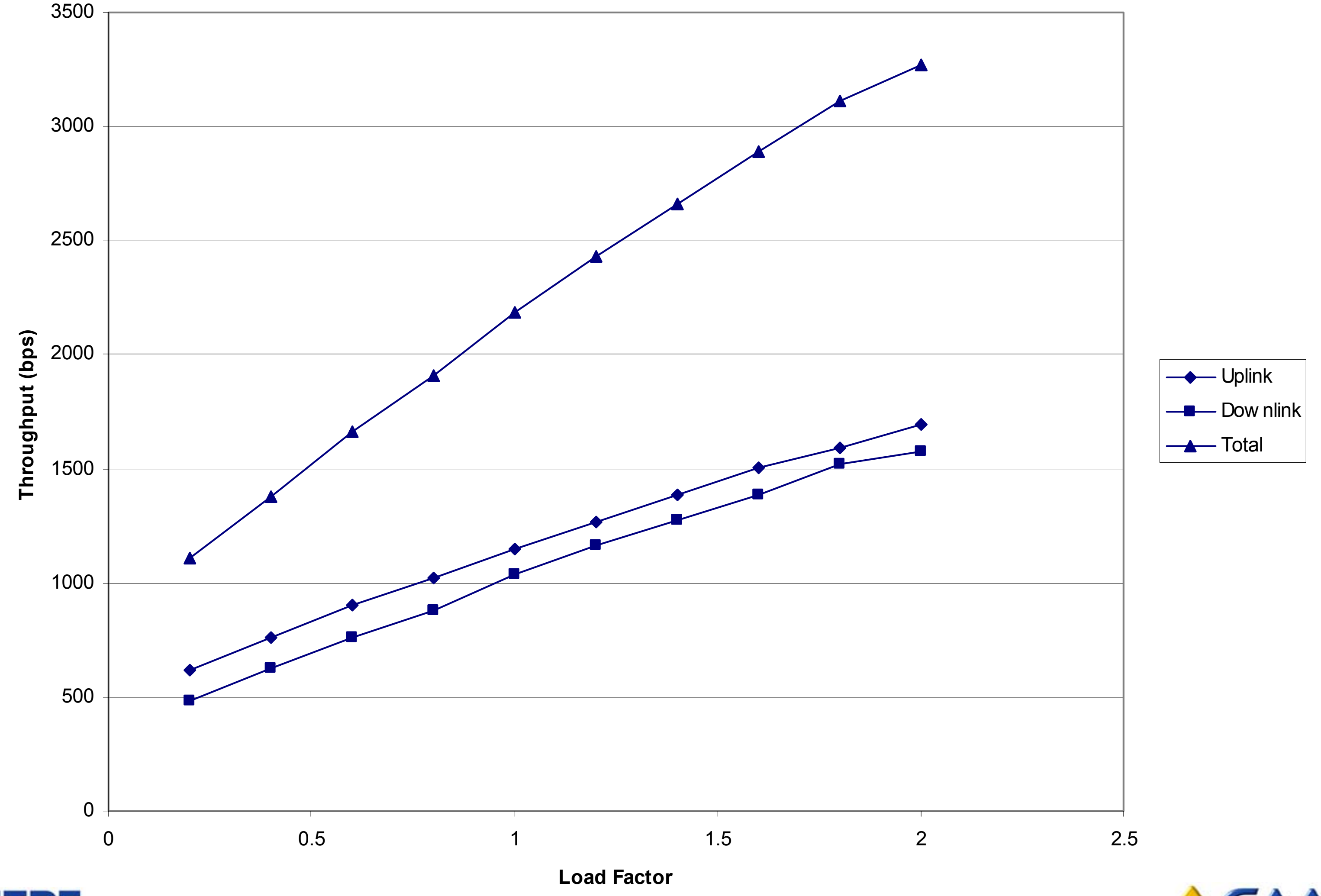
34 AC Throughput (A_L = 20 sec, T1 = 221 sec)



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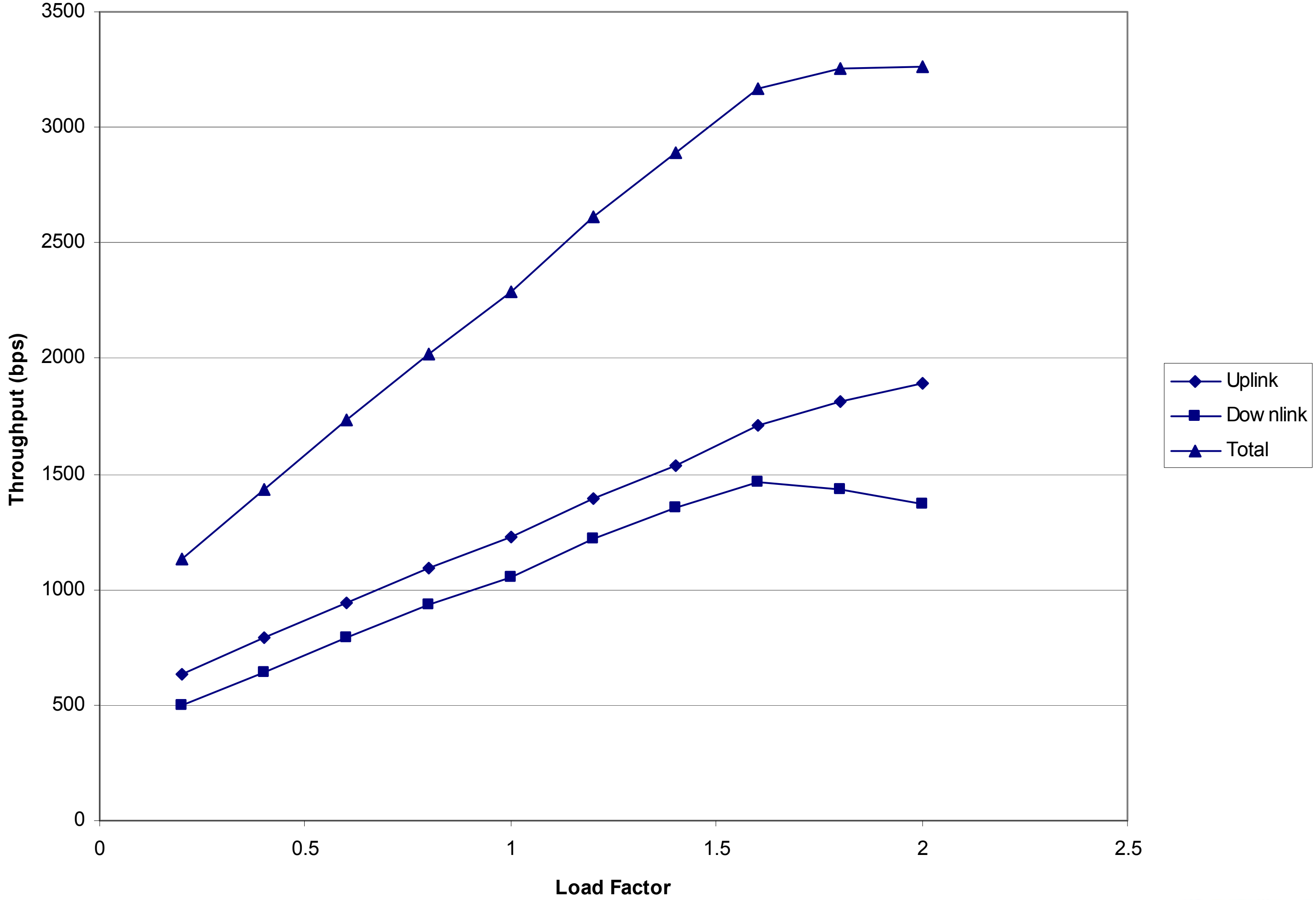
34 AC Throughput (A_L = 1 sec, T1 = 202 sec)



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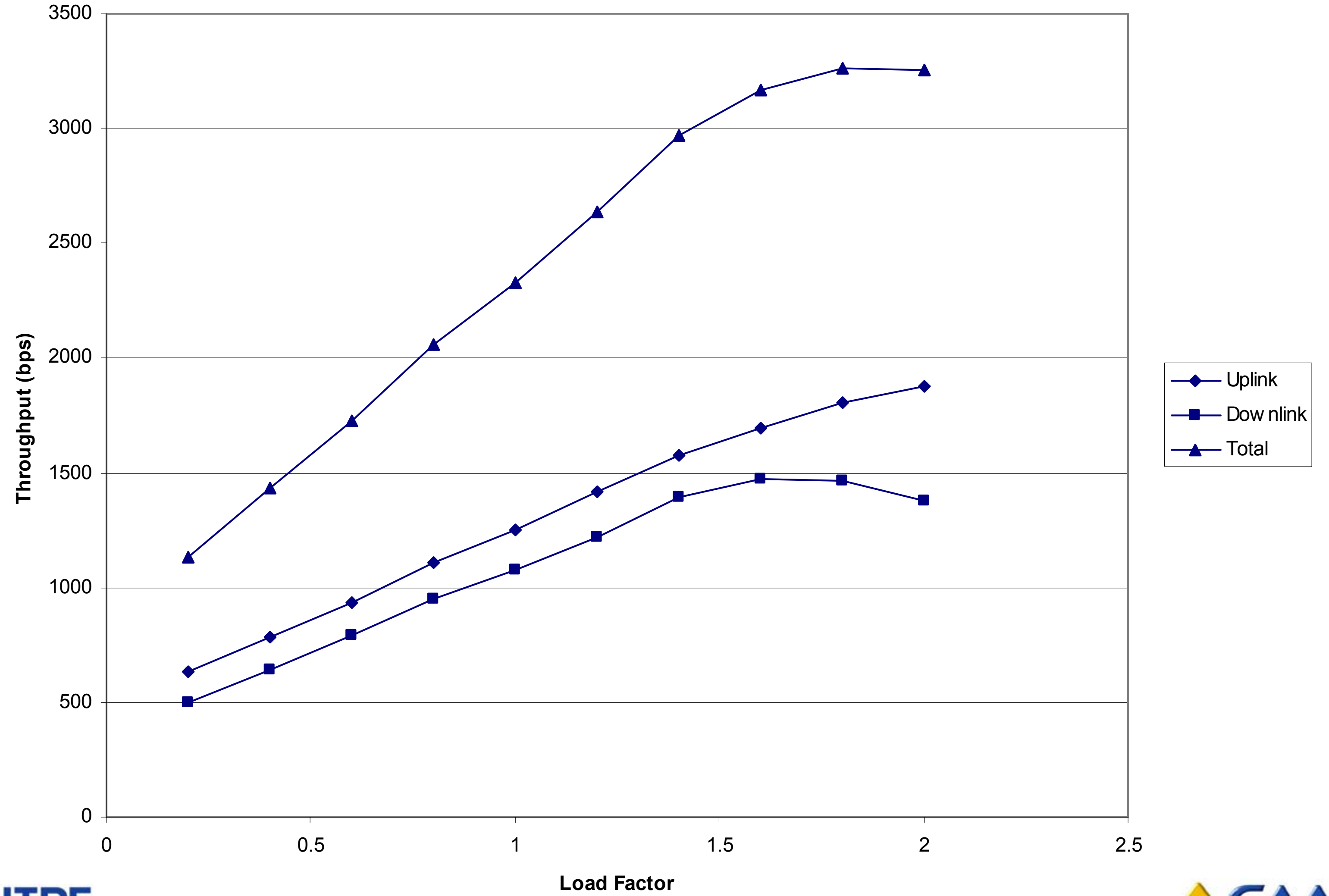
34 AC Throughput (A_L = 1 sec, T1 = DLRTA)



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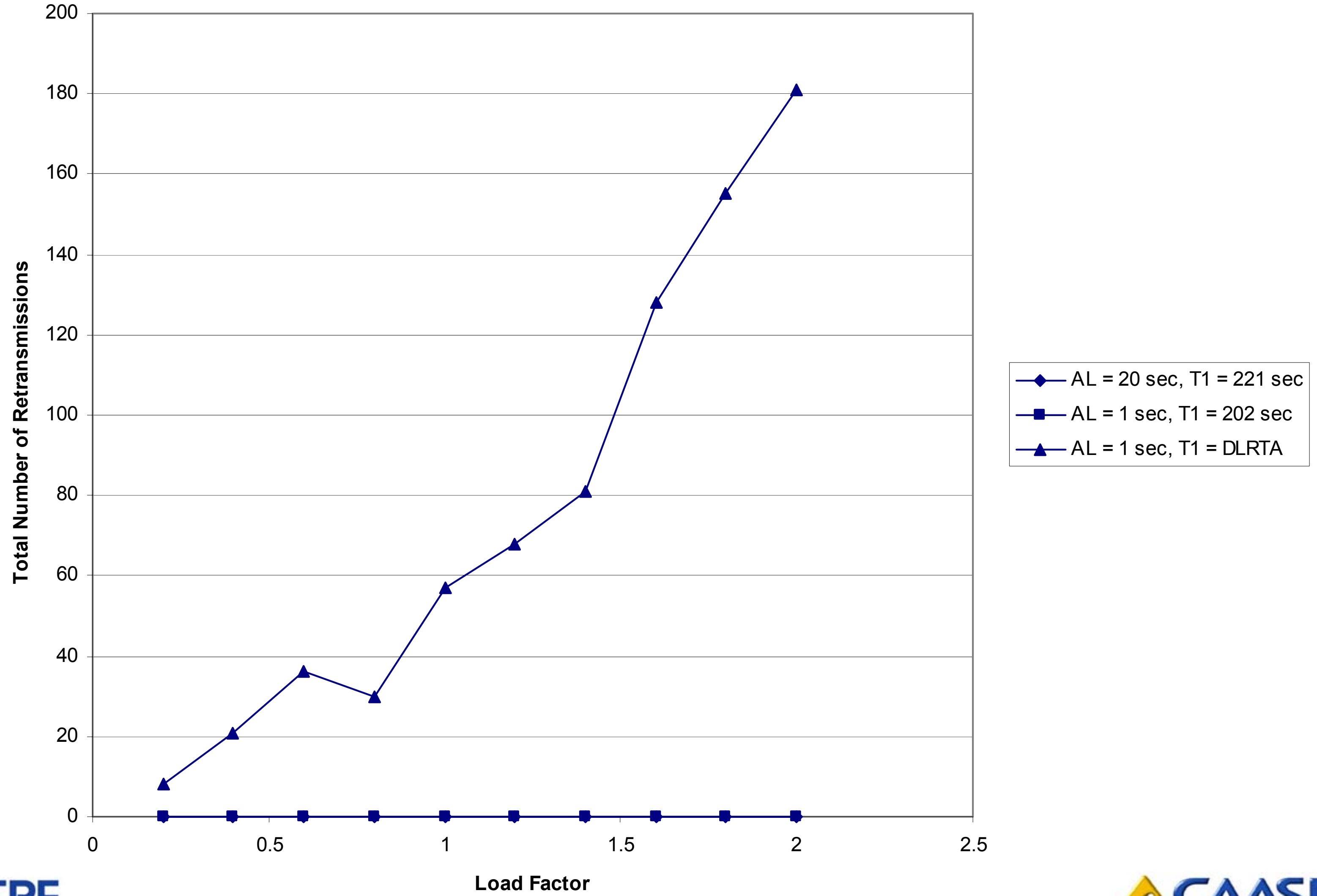
26 AC Total Number of Retransmissions



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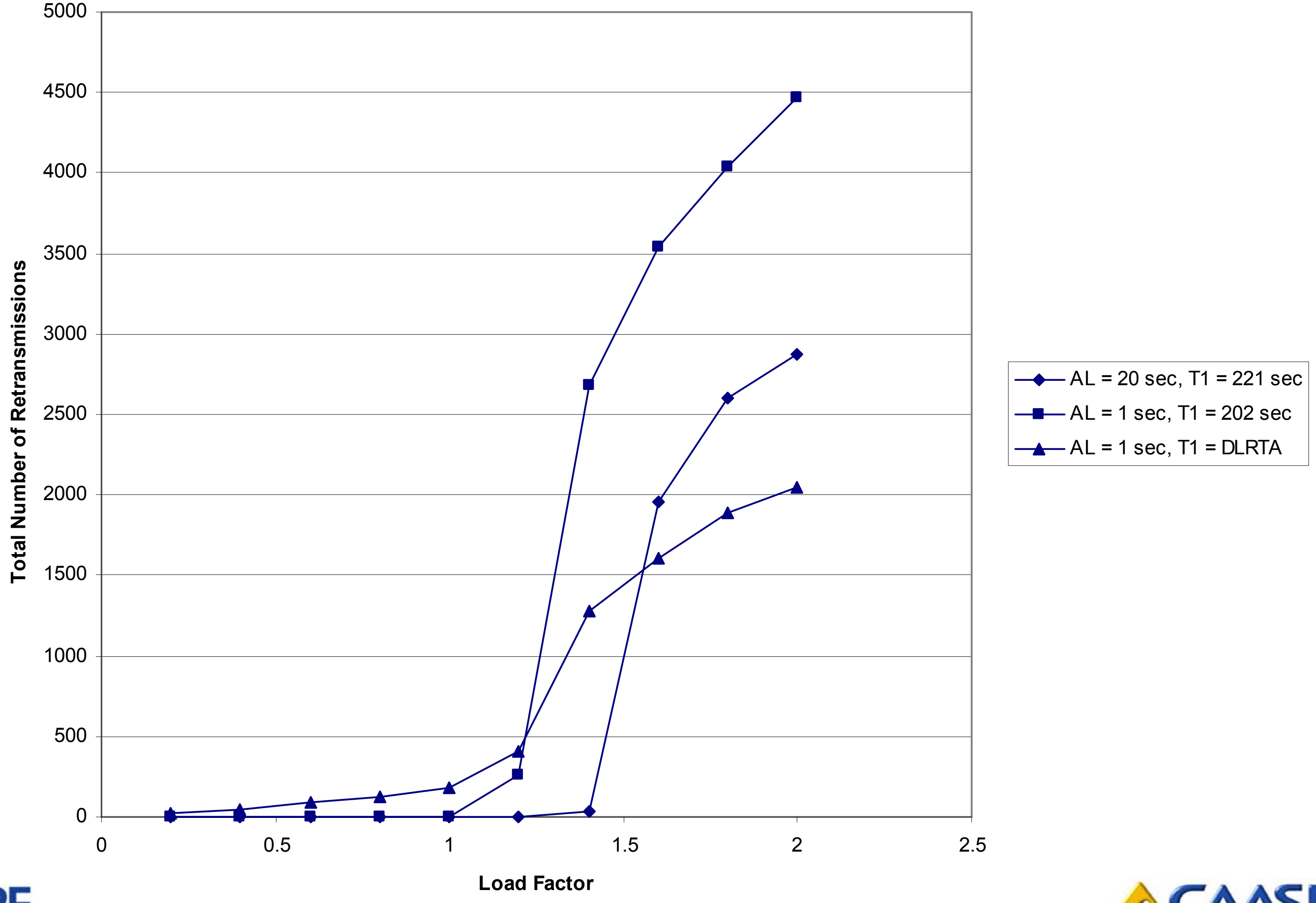

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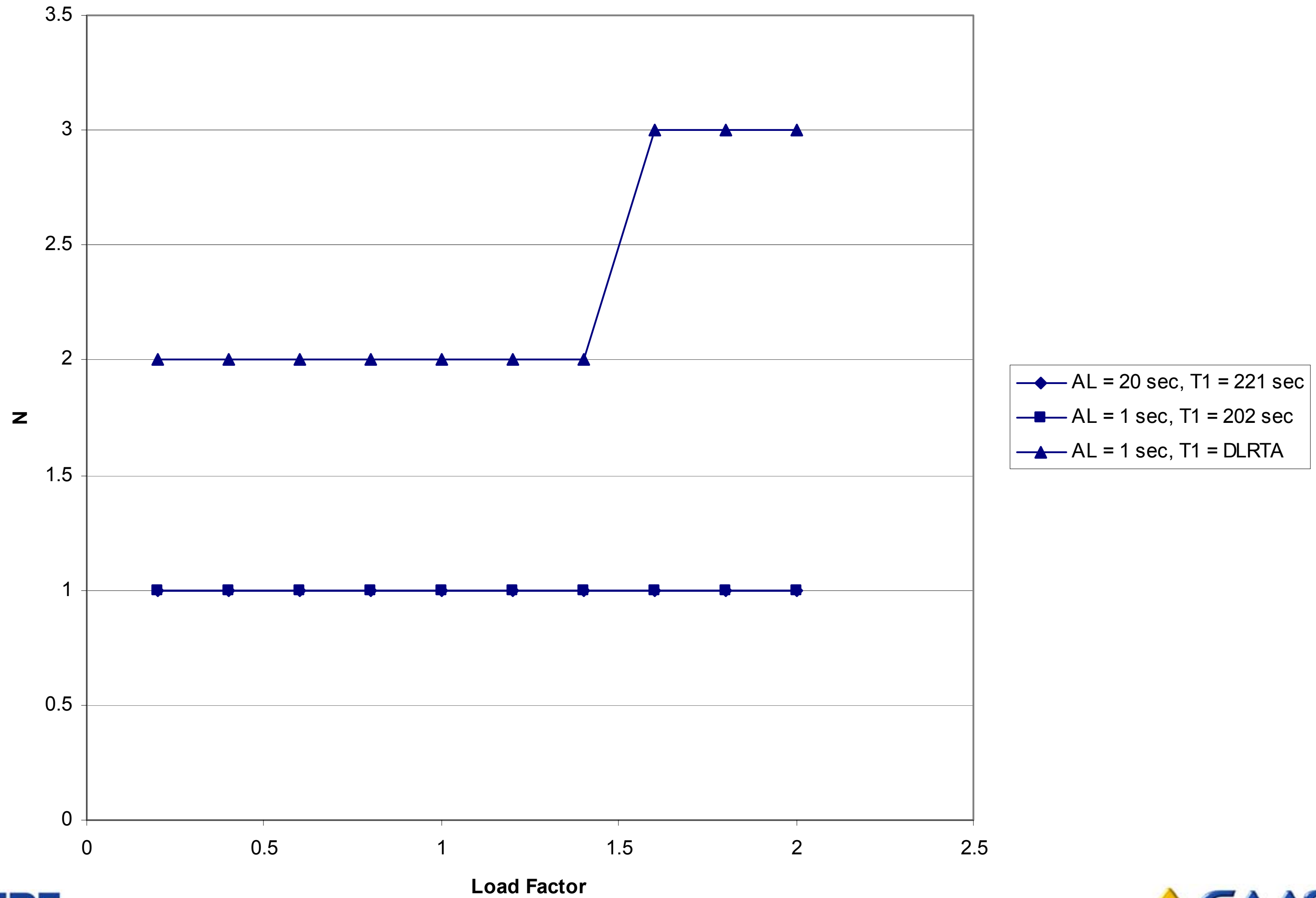

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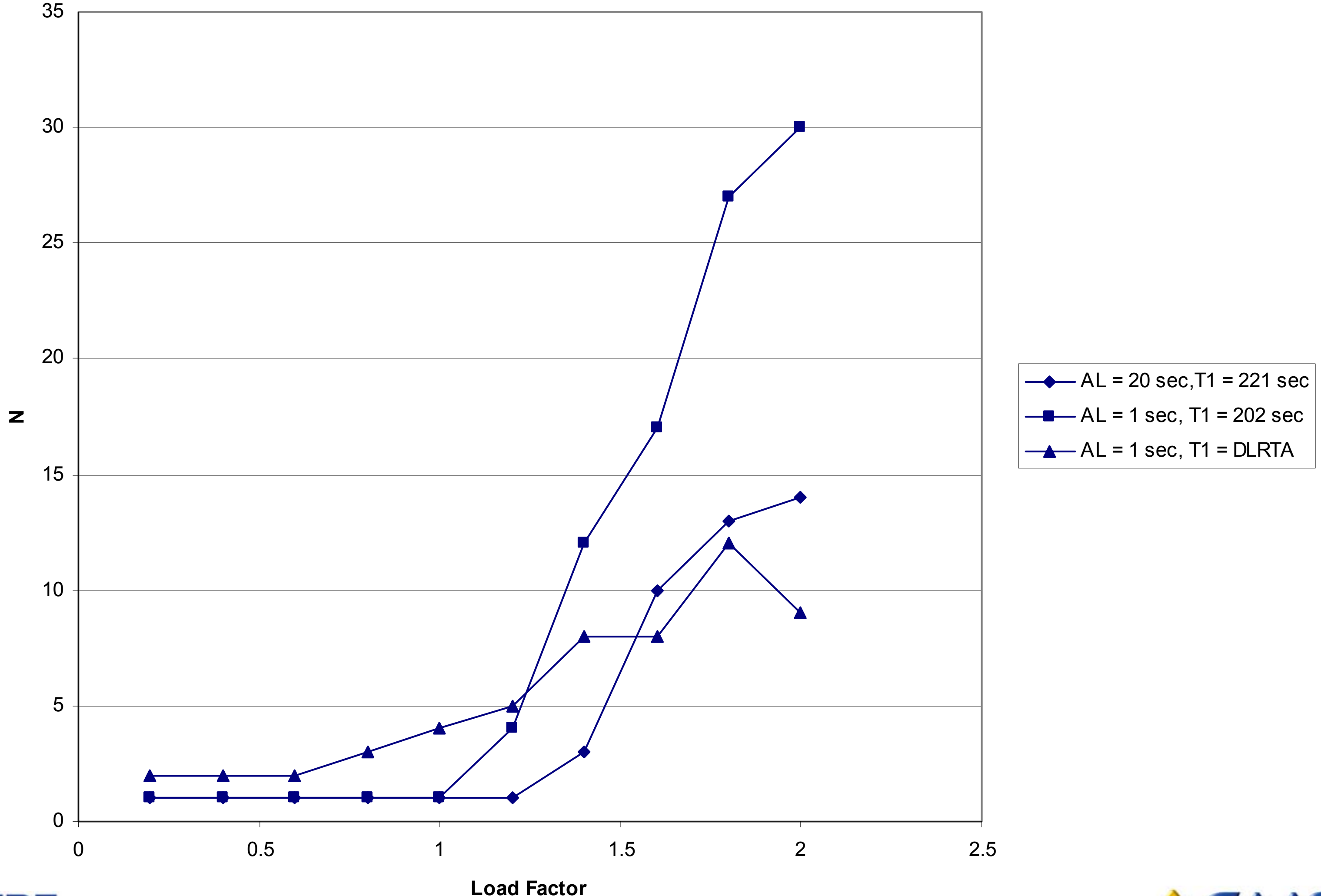

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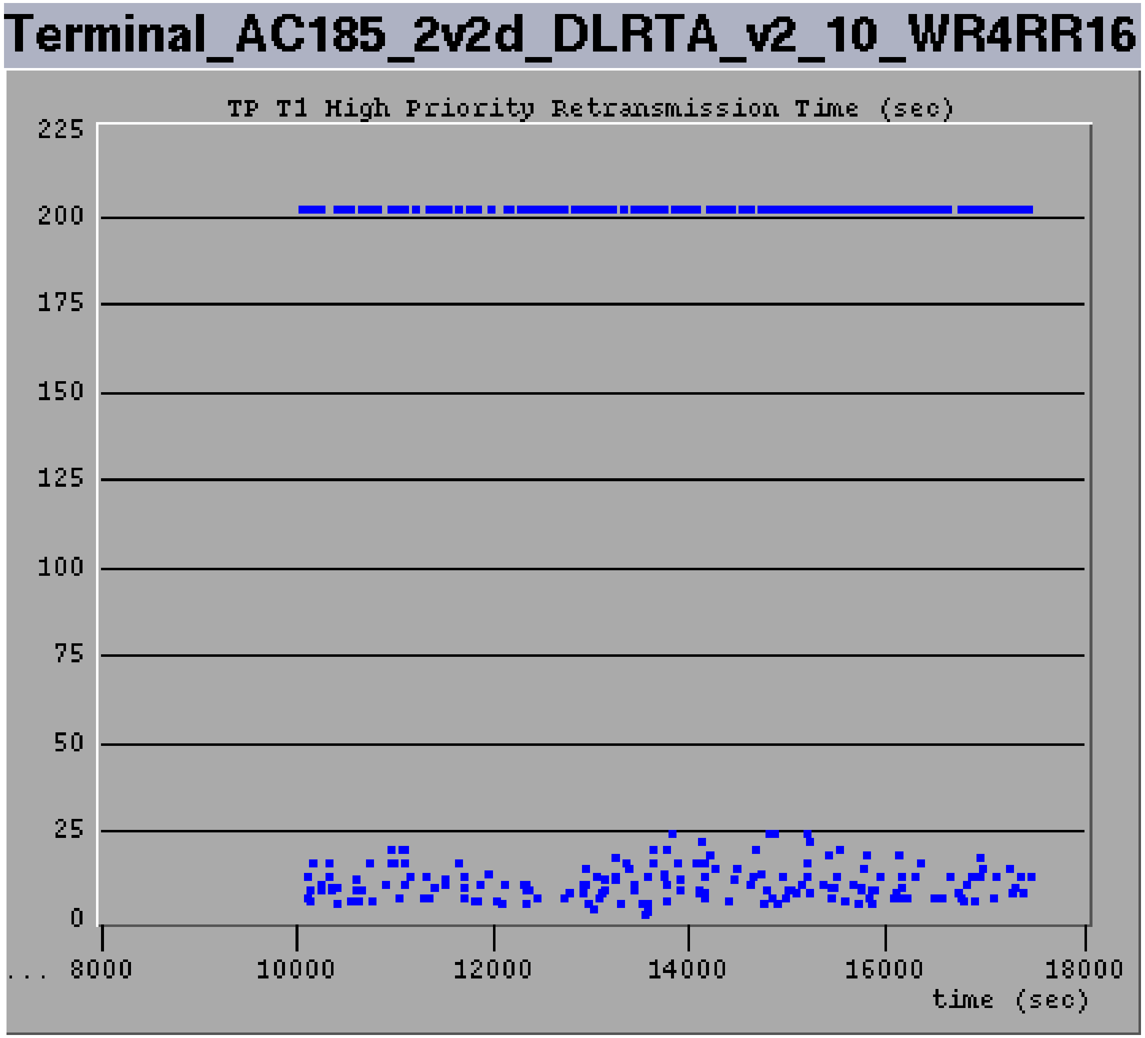
34 AC T1 Values Using DLRTA Algorithm (1 LF)



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Dynamic Local Retransmission Time Adaptation Algorithm

- **Initial value**
  - $SRTT_{init} = S_0$
  - $D_{init} = SRTT_{init}/4$
  - $T1_{init} = SRTT_{init} + 4*D_{init} + A_R$
    - $T1_{init}$ **Initial value of the local retransmission time**
    - $SRTT_{init}$ **Initial round trip time estimate**
    - D_{init} $SRTT_{init}$ **mean estimate**
    - S_0 **First valid round-trip time sample**
    - A_R **Remote acknowledgement time value**
- **Subsequent values**
  - $Err = S - SRTT_{prev}$
  - $SRTT_{new} = SRTT_{prev} + g * Err$
  - $D_{new} = D_{prev} + h * (ABS(Err) - D_{prev})$
  - $T1 = SRTT_{new} + 4 * D_{new} + A_R$

Dynamic Local Retransmission Time Adaptation Algorithm (Continued)

- *T1* Local retransmission time
- *SRTT* Smoothed round-trip time
- *D* Mean deviation
- $SRTT_{prev}$ and $SRTT_{new}$ are the previous and new computed values of the "smoothed" round trip time estimate. Initially, $SRTT_{prev}$ is set to $SRTT_{init}$
- D_{prev} and D_{new} are the previous and new computed values of the "smoothed" mean deviation. Initially, D_{prev} is set to D_{init}
- *Err* is the difference between the measured value just obtained *(S)* and the previous $SRTT_{prev}$
- The gains *g* and *h* are constants that control how rapidly the smoothed round-trip time and its smoothed mean deviation adapt to change. *g* is set to *1/8*. *h* is set to *1/4*.

Dynamic Local Retransmission Time Adaptation Algorithm (Concluded)

- *ABS(Err)* is the absolute value of *Err*
- *T1* is the Local Retransmission Time value
- A_R is the Remote Acknowledgement Time value

- This algorithm is derived from the Jacobson's algorithm and differs only by the addition of the Remote Acknowledgement Time (A_R) in the formula used for the computation of the Local Retransmission Time value.
- The *SRTT*, *D* and *T1* variables are maintained on a per transport connection basis

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Summary and Observations (Concluded)

- The delays are shorter for A_L = 20 seconds and T1 = 221 seconds for 34 aircraft at higher LFs
- The throughputs are higher at the application layer for A_L = 20 seconds and T1 = 221 seconds for 34 aircraft at higher LFs
- The total number of retransmissions are lower for A_L = 20 seconds and T1 = 221 seconds
- The maximum number of transmissions, N, are lower for A_L = 20 seconds and T1 = 221 seconds